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Symbiotic Relationships: Cnidarians, Fungi, and Protozoa

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Symbiotic Relationships: Cnidarians, Fungi, and Protozoa

Practice: 8 MCQs



Coral polyps with their tentacles extended. Reef-building corals share their tissue with algae. Photo by David Burdick / NOAA, Wikimedia Commons, Public domain.

Symbiosis means unlike species living closely together. This article covers corals and algae, termites and gut protozoa, lichens, mycorrhizae and root nodules. It also explains endosymbiosis and why the textbook calls anemonefish commensal.

- **Three types:** mutualism, commensalism and parasitism. Symbiosis covers all of them.
- **Cnidarians:** corals share tissue with zooxanthellae algae.

- **Fungi:** lichens and mycorrhizae.
- **Protozoa:** Cleveland tested termites and their gut protozoa in the 1920s.
- **UPSC 2021:** all three groups have symbiotic species.

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1. What is symbiosis, and what kinds are there?

Symbiosis means different species living closely together. The partners do not always gain equally. This section sorts the types before the exam examples.

1.1 What does the word symbiosis mean?

De Bary defined symbiosis in 1879 as **the living together of unlike organisms**.

Researchers today say symbiotic associations form a gradient. The gradient includes mutualistic, commensal and even parasitic relationships. These associations can also shift when conditions change.

So the word only says that the partners live together.

1.2 How do mutualism, commensalism and parasitism differ?

The Class 12 biology book separates the three types by who gains.

- **Mutualism.** Both species benefit.
- **Commensalism.** One species benefits. The other is neither harmed nor benefited.
- **Parasitism.** One species benefits. The other, the host, is harmed.

The same book gives these examples.

- **Mutualism:** lichens, and mycorrhizae.
- **Commensalism:** an orchid growing as an epiphyte on a mango branch, and barnacles on the back of a whale. The cattle egret with grazing cattle is also called a classic example.
- **Parasitism:** lice on humans, ticks on dogs, and Cuscuta. Cuscuta is a parasitic plant that has lost its chlorophyll and leaves.

The egret example shows how commensalism works. Egrets forage close to grazing cattle. The cattle stir up and flush out insects that are hard for the egrets to find.

Symbiosis covers all three types. Mutualism is only one of them.



Who gains in each type. Original explanatory diagram.

Sources:

- Raina et al. 2018
- Class 12 biology book: Organisms

Symbiosis always means that both partners benefit.

2. Which groups have symbiotic species?

The exam asks whether cnidarians, fungi and protozoa all have symbiotic species. The answer is yes for all three.

2.1 How do cnidarians take part?

Corals and sea anemones are cnidarians. Most reef-building corals contain photosynthetic cells called **zooxanthellae**. These cells live in the coral's tissues.

Sea anemones also partner with algae of the family Symbiodiniaceae. The algae sit inside the animal's tissue. They make sugars by photosynthesis. The sugars support the host's growth and reproduction.

2.2 How do fungi take part?

Fungi form two well-known partnerships.

- **Lichens.** A fungus lives with photosynthesising algae or cyanobacteria.
- **Mycorrhizae.** Fungi live with the roots of higher plants.

2.3 How do protozoa take part?

Some protozoa live in the gut of termites. Lemuel Cleveland reported in the 1920s that termites need them to live on wood. Section 4 tells that story.

Sources:

- Class 12 biology book: Organisms
- NOAA: zooxanthellae page
- Cleveland memoir (NAS)
- Pryor et al. 2020

Remember this: which groups have symbiotic species?

Cnidarians, fungi and protozoa all do. Corals share tissue with algae. Fungi form lichens and mycorrhizae. Some protozoa live in termite guts.

3. How do zooxanthellae power a coral reef?

Reef-building corals have algae called zooxanthellae living in their tissues. NOAA calls this a mutualistic relationship.

3.1 What does each partner give?

NOAA calls the coral and zooxanthellae partnership mutualistic. Each side gives something.

- The coral gives the algae a **protected environment**.
- The coral's polyp cells make carbon dioxide and water. The algae need both for photosynthesis.
- The algae supply the coral with the building blocks of **sugars and proteins**.
- The coral uses these products to make proteins, fats and carbohydrates. It also uses them to produce calcium carbonate.

3.2 How much of the algae's food reaches the coral?

As much as **90 percent** of the organic material that the algae make by photosynthesis is transferred to the coral tissue. NOAA calls this the driving force behind the growth and productivity of coral reefs.

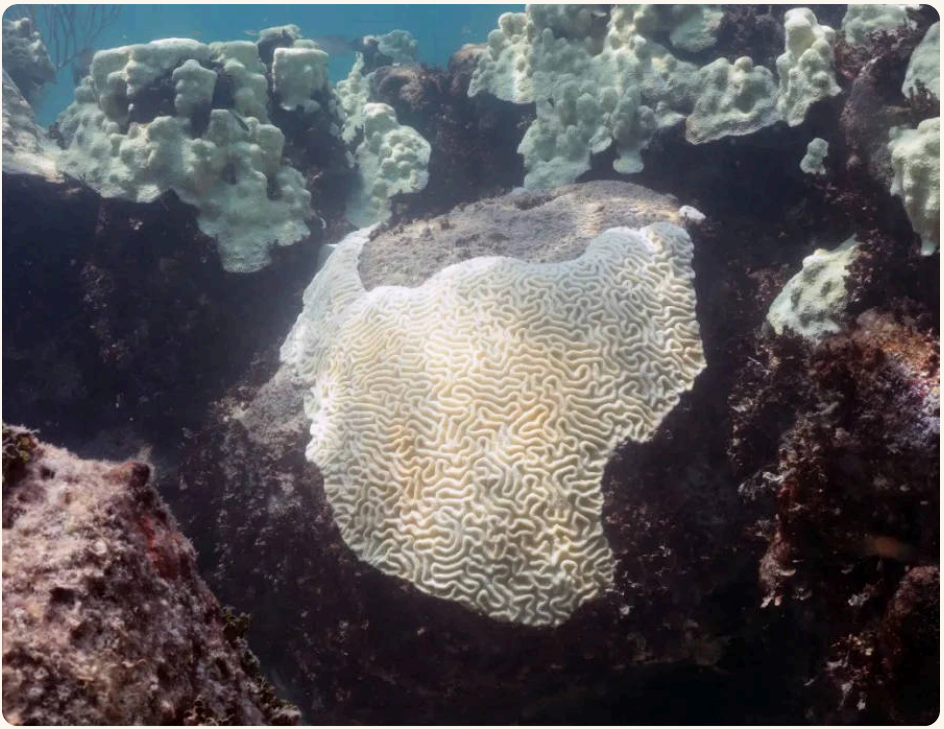
The algae also give many stony corals their colours.

3.3 What is coral bleaching?

Sometimes conditions change. NOAA lists changes in temperature, light or nutrients as stress factors. Stressed corals expel the algae living in their tissues. The coral then turns completely white. This is **coral bleaching**.

NOAA says a coral that bleaches is not dead. Corals can survive a bleaching event, but they are under more stress. If the algae loss is prolonged and the stress continues, the coral eventually dies.

Why can a long bleaching be fatal? Bleaching cuts the sugars that reach the host. If the cnidarian stays bleached for a prolonged period, starvation can result in death.



Bleached coral in the Florida Keys. The coral has lost its algae and turned white. Photo by NOAA, Wikimedia Commons, Public domain.

3.4 How big was the fourth global bleaching event?

NOAA confirmed on 15 April 2024 that the world was in its fourth global coral bleaching event.

- From 1 January 2023 to 30 September 2025, bleaching-level heat stress affected about **84.4%** of the world's coral reef area.
- The previous record was **68.2%**, in the third event of 2014 to 2017.
- Mass coral bleaching was documented in at least 83 countries and territories.

The figure counts reef area under bleaching-level heat stress. NOAA says the event likely ended in 2025.



Reef area under bleaching-level heat stress. Original explanatory diagram.

Sources:

- NOAA: zooxanthellae page
- NOAA: coral bleaching page
- Pryor et al. 2020
- NOAA Coral Reef Watch status

Zooxanthellae live in coral tissue and pass much of the food they make to the coral.

4. What did the termite experiments show?

How do scientists know termites truly depend on their gut protozoa? Lemuel Cleveland tested the idea in the 1920s. His story also shows how science checks old results.

4.1 What did Cleveland find?

Cleveland did this work as a fellow at the Johns Hopkins University School of Hygiene. His papers came out between 1923 and 1928. He worked on termites and the protozoa in their guts.

- He removed the protozoa. His methods included incubation at **35 C**, exposure to pure oxygen, and starvation.
- The termites still had their gut bacteria and spirochetes.
- On a diet of only wood or cellulose, the termites without protozoa died of starvation.
- Termites that were reinfected with the protozoa were saved.

The National Academy of Sciences memoir calls this a first. It was the first instance in which a mutualistic relationship between internal microorganisms and their animal host was clearly proved.



Mastotermes darwiniensis, a termite species. Photo by CSIRO, Wikimedia Commons, CC BY 3.0.

4.2 Did later work change the picture?

Partly, yes. Later researchers checked Cleveland's experiment again.

- Two groups said it was not enough to prove the partnership. They noted that the treatments could have damaged the termites.
- Another study found that termites still broke down labelled cellulose after the protozoa were removed. Its authors suggested that termites have their own cellulose-digesting activity.

A 2003 study describes lower termites this way. Cellulose seems to be broken down by flagellates, bacteria and yeasts together. The termite's own cellulases also help.

So the protozoa are important partners. They are not the only digesters.

Sources:

- Cleveland memoir (NAS)
- Kanai et al. 1982
- Li et al. 2003

In Cleveland's experiments, termites without gut protozoa lived well on a wood diet.

Think it through: why can the protozoa not be called the only digesters?

Later work found that termites still broke down cellulose without the protozoa. In lower termites, bacteria, yeasts and the termite's own cellulases also help.

5. Why did the lichen story gain a third partner?

Lichens were long taught as a two-way deal. One fungus joined one photosynthetic partner. A 2016 study changed that picture.

5.1 Who are the two classic partners?

The Swiss botanist Simon Schwendener studied lichens. He was the first scientist to propose that some organisms are combinations of unrelated species.

He saw that a lichen is a fungus plus a photosynthetic partner. The partner is an alga or a cyanobacterium.

- The alga or cyanobacterium makes food. It turns sunlight and carbon dioxide into **sugars**.
- The fungus forms the main structure of the lichen.
- The fungus also protects its partner from the environment.



A lichen on rock. A lichen is a fungus living with an alga or cyanobacterium. Photo by Joshua Tree National Park, Wikimedia Commons, Public domain.

5.2 What did the 2016 study find?

A study led by the University of Montana appeared in Science on 21 July 2016. It found a third partner embedded in the lichen cortex, or “skin”. The partner is a yeast.

- The yeasts are basidiomycetes. They are single-celled fungi.
- They were found in lichens across **six continents**.
- Related yeast lineages turned up in **52 genera** of lichens worldwide.

The yeasts likely make chemicals that help lichens ward off predators and repel microbes.

5.3 Why did the yeast matter?

The work began with a puzzle. Two lichens seemed to share the same fungus and alga.

- *Bryoria tortuosa* is yellow and makes a toxic substance called vulpinic acid.
- *B. fremontii* is dark brown and makes none.

The yeast could explain such differences. It could also explain why scientists have been unable to build lichens in the laboratory. They failed even when they combined species that partner successfully in nature.

Sources:

- Purdue release 2016
- Class 12 biology book: Organisms
- Spribille et al. 2016 abstract

A 2016 study found a yeast living as a third partner in many lichens.

6. How do mycorrhizae help plants and fungi?

Mycorrhizae are the second fungal partnership in the exam list.

6.1 What does each side gain?

The fungus helps the plant absorb essential nutrients from the soil. The plant gives the fungus **energy-yielding carbohydrates**.

Members of the genus *Glomus* show this well. The fungal partner absorbs **phosphorus** from the soil and passes it to the plant. Such plants also show other benefits.

- Resistance to root-borne pathogens.
- Tolerance to salinity and drought.
- An overall increase in plant growth and development.

6.2 How common is this partnership?

A 2018 review in New Phytologist found that the **majority** of vascular plants are mycorrhizal. About 72% form arbuscular mycorrhizas. Just 8% are completely non-mycorrhizal.

Sources:

- Class 12 biology book: Organisms
- Class 12 biology book: Microbes
- Brundrett and Tedersoo 2018

Remember this: what does each side gain in a mycorrhiza?

The fungus helps the plant absorb nutrients from the soil. In return, the plant supplies the fungus with energy-yielding carbohydrates.

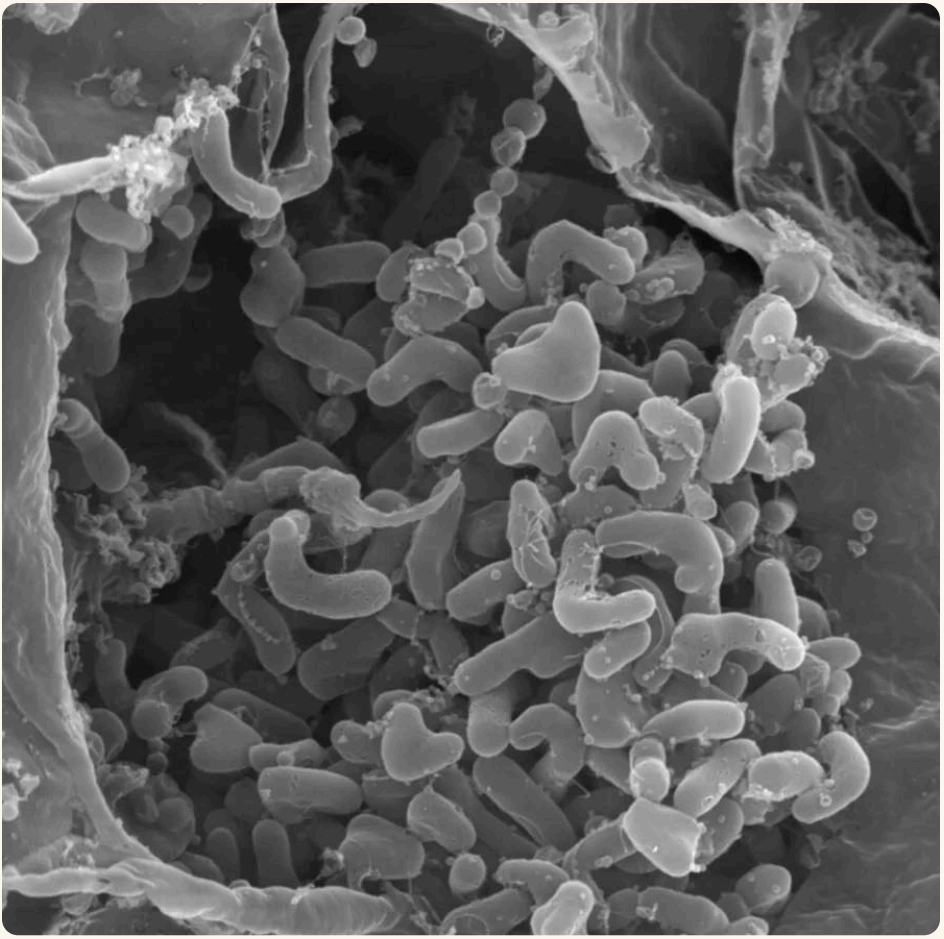
7. Do plants and bacteria strike the same deal?

Cnidarians, fungi and protozoa are not the only groups. Plants run a similar trade with bacteria.

7.1 What happens inside a root nodule?

Clover, alfalfa and other legumes provide a home for bacteria called **rhizobia**. The bacteria live in nodules. They induce the plant to build these nodules on its roots.

Inside the nodules, the bacteria convert nitrogen from the air into ammonia. The plant can use it as a nutrient. The plant feeds the bacteria with carbon compounds called **dicarboxylates**.



Nitrogen-fixing bacteria inside the cells of a legume root nodule. Photo by LegumeLover, Wikimedia Commons, CC BY 4.0.

7.2 Is it the same trade as coral and algae?

The sources describe three exchanges.

- **Coral and algae.** The coral gives a protected home and carbon dioxide. The algae give sugars and building blocks of proteins.
- **Fungus and plant.** The plant gives carbohydrates. The fungus helps absorb nutrients such as phosphorus.

- **Legume and rhizobia.** The plant gives a home and carbon compounds. The bacteria give ammonia made from air nitrogen.

What each partner gives

Algae give coral	sugars
Coral gives algae	home, CO2
Plant gives fungus	carbohydrates
Fungus gives plant	phosphorus
Legume gives	carbon compounds
Rhizobia give	ammonia

Sources: NOAA, Class 12 book, USDA.

The trade in three partnerships. Original explanatory diagram.

Sources:

- USDA ARS magazine 1995
- Science Advances 2021 paper
- Class 12 biology book: Microbes
- NOAA: zooxanthellae page

8. What is endosymbiosis?

Margulis proposed that some parts of complex cells began as separate cells.

8.1 What did Margulis propose?

In March 1967 Lynn Sagan, later known as Lynn Margulis, published "On the Origin of Mitosing Cells". It appeared in the Journal of Theoretical Biology.

She proposed that mitochondria, plastids and basal bodies were once **free-living cells**. They took up residence inside primitive eukaryotic cells. She called this process **endosymbiosis**.

8.2 Which features fit the idea?

The Class 11 biology book describes these features of the organelles.

- Mitochondria are bound by a **double membrane**.
- The mitochondrial matrix holds a single circular DNA molecule, a few RNA molecules and 70S ribosomes.
- Mitochondria divide by fission.
- Chloroplasts are also double membrane bound. They contain small, double-stranded circular DNA molecules and ribosomes.

A 2020 review notes that bacteria and mitochondria both contain circular DNA and divide through fission. It adds that the double membrane may act in favour of the endosymbiotic theory.

Sources:

- Embryo Project (ASU)
- Class 11 biology book: Cell
- Molecules 2020 paper

Explain it back: what is endosymbiosis?

Margulis proposed that mitochondria and plastids were once free-living cells. They took up residence inside primitive cells. She published this as Lynn Sagan in 1967.

9. Which other partnerships are worth knowing?

The same trade shows up in very different bodies. One of these examples is classed differently by different sources.

9.1 Are anemonefish and sea anemones mutualists?

NCERT calls this pair commensalism. The fish gets protection from predators, which stay away from the stinging tentacles. The anemone does not appear to derive any benefit.

A 2020 paper notes that anemonefish give their hosts **numerous benefits**. These include ammonia from the fish's waste. So a 2020 paper points to a two-way benefit. For a textbook question, follow the book and answer commensalism.



A dusky anemonefish in a leathery sea anemone. Photo by Paul Asman and Jill Lenoble, Wikimedia Commons, CC BY 2.0.

9.2 How does the bobtail squid use its bacteria?

The Hawaiian bobtail squid hosts the bacterium *Vibrio fischeri* in a light organ. The bacteria produce light.

- The squid uses the light as camouflage.
- This behaviour is called **counterillumination**. It disrupts the squid's silhouette.
- Only *V. fischeri* colonises the light organ.

The same review says the bacteria switch their metabolism. They use glycerol phosphate respiration in the day and chitin fermentation at night.



A Hawaiian bobtail squid. Its light organ holds glowing bacteria. Photo by Margaret McFall-Ngai, Wikimedia Commons, CC BY 4.0.

9.3 What do acacia trees give their ants?

Some Mesoamerican acacias are “obligate ant plants”. They provide **nesting space** in hollow thorns. They also give food rewards. The rewards are extrafloral nectar and food bodies. The ants are defending *Pseudomyrmex* ants.

A study found that acacias giving higher rewards were more effectively defended against herbivores.



Pseudomyrmex ants on the thorns of a bullhorn acacia. Photo by ImagePerson, Wikimedia Commons, CC BY 4.0.

Sources:

- Class 12 biology book: Organisms
- Pryor et al. 2020
- Nyholm and McFall-Ngai 2021
- Heil et al. 2009

The Class 12 biology book calls the anemonefish and sea anemone pair mutualism.

10. Why does losing one partner hurt so much?

Two of the partnerships above show what happens when a partner is lost.

10.1 What happens when a partner is lost?

- **Termites.** Without gut protozoa, Cleveland's termites starved on wood.
- **Corals.** Without their algae, corals bleach. A long bleaching can end in starvation.

Sources:

- Cleveland memoir (NAS)
- Pryor et al. 2020

11. How do exams test this?

UPSC asked this topic as a list question.

11.1 What did UPSC ask in 2021?

UPSC Civil Services Prelims 2021, Q30, asked which of these have species that can establish symbiotic relationships with other organisms: cnidarians, fungi and protozoa. The answer is **all three**.

11.2 Which traps should you avoid?

- Symbiosis is wider than mutualism.
- A lichen is a fungus with an alga or a cyanobacterium.
- A mycorrhiza is a fungus with the roots of higher plants.
- A bleached coral has lost its algae. It is not dead.
- The textbook calls anemonefish and anemones commensal.

Sources:

- UPSC CSP 2021 paper page
- Class 12 biology book: Organisms
- NOAA: zooxanthellae page

- Cleveland memoir (NAS)
- Raina et al. 2018
- NOAA: coral bleaching page

Your understanding checks

Your 5 quick checks Answered 0 of 5 · Correct 0
This score resets when the page reloads.

Practice: 8 MCQs

Practice MCQs

1. What do zooxanthellae provide to their coral host?

A. Physical protection only

B. Nothing, the relationship is one-sided

C. Nutrients through photosynthesis

D. Reproductive cells

See answer ↓

2. What are the two partners in a lichen?

A. Two different fungi

B. Two different bacteria

C. A fungus and an alga or cyanobacteria

D. A plant and an animal

See answer ↓

3. What is coral bleaching?

A. Corals changing color to attract prey

B. Corals turning white after expelling their zooxanthellae under heat stress

C. A natural coral growth process

D. A disease unrelated to temperature

See answer ↓

4. How do protozoa help termites in their symbiotic relationship?

A. By producing wood for the termite nest

B. By protecting termites from predators

C. By digesting cellulose so termites can extract nutrients from wood

D. By generating heat inside the colony

See answer ↓

5. Lichens represent a mutualistic, symbiotic association between which two organisms?

A. A fungus and the roots of higher plants

B. A fungus and mosses

C. A fungus (mycobiont) and an alga (phycobiont)

D. A fungus and a virus

See answer ↓

6. Mycorrhizae represent a mutualistic, symbiotic association between fungi and which structure?

A. The roots of higher plants

B. Bryophytes specifically

C. Non-vascular plants specifically

D. Vascular plants broadly, excluding roots

See answer ↓

7. Legumes like alfalfa, chickpea, and clover fix nitrogen through a symbiotic relationship with which organism in their root nodules?

A. Cyanobacteria exclusively

B. Earthworms

C. Mycorrhizal fungi only

D. Rhizobium bacteria

See answer ↓

8. Biologically, what is a lichen?

A. A single-celled fungus

B. A moss species found only in cold climates

C. A symbiosis between a fungus and algae or cyanobacteria

D. A type of flowering plant

See answer ↓

Answer Key

1. **C.**
   Zooxanthellae are photosynthetic algae that live in coral tissue. They make sugars and the building blocks of proteins. As much as 90 percent of the organic material they make is transferred to the coral. So the coral gets nutrients through photosynthesis.
   ↑ Q1
2. **C.** The correct answer is **a fungus and an alga or cyanobacteria**. A lichen is a fungus with a photosynthetic partner. Most of the lichen is fungal filaments, with algal cells living among them. The 'two fungi' option is wrong because the second partner must be photosynthetic. The 'two bacteria' option is wrong because a lichen needs a fungus. The 'plant and an animal' option is wrong because neither is a lichen partner. Memory hook: one fungus plus one food-maker. ↑ Q2
3. **B.**
   Stressed corals expel the algae living in their tissues. NOAA lists changes in temperature, light or nutrients as stress factors. The coral then turns completely white. Corals can survive a bleaching event. A long loss of algae can kill the coral.
   ↑ Q3
4. **C.**
   Cleveland found in the 1920s that termites without gut protozoa starved on a wood diet. The protozoa help digest cellulose. Later work on lower termites shows that gut bacteria, yeasts and the termite's own cellulases also help. So the protozoa are key partners, but not the only digesters.
   ↑ Q4
5. **C.** The correct answer is **a fungus and an alga**. A lichen is a stable symbiotic association between a fungus and algae or cyanobacteria, says the British Lichen Society. The alga makes food from sunlight and the fungus builds the body. The 'roots of higher plants' option is wrong because a lichen's partner is an alga or cyanobacterium, not plant roots. The 'virus' option is wrong because a virus is not a photosynthetic partner. The 'mosses' option is wrong because no source lists a moss as a lichen partner. Memory hook: lichen means fungus plus a food-maker. ↑ Q5

6. **A.**

   Mycorrhizae are partnerships between fungi and the roots of higher plants. The fungus helps the plant absorb essential nutrients from the soil. The plant gives the fungus energy-yielding carbohydrates. The fungus Glomus, for example, absorbs phosphorus and passes it to the plant.

   ↑ Q6

7. **D.**

   Legumes such as clover and alfalfa host bacteria called rhizobia in root nodules. Inside the nodules, the bacteria convert nitrogen from the air into ammonia. The plant can use ammonia as a nutrient. The plant feeds the bacteria with carbon compounds called dicarboxylates.

   ↑ Q7

8. **C.**

   A lichen is a symbiosis. A fungus lives with an alga or a cyanobacterium. The alga or cyanobacterium makes food from sunlight and carbon dioxide. The fungus forms the main structure and protects its partner.

   ↑ Q8

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